Claims

[c1] An apparatus for generating a strongly-ionized plasma, the apparatus comprising:

an ionization source that generates a weakly-ionized plasma from a volume of feed gas;

a power supply that applies an electrical pulse across the weakly-ionized plasma to generate the strongly-ionized plasma; and

a means for exchanging the strongly-ionized plasma with a second volume of feed gas while applying the electrical pulse across the second volume of feed gas to generate an additional strongly-ionized plasma.

[c2] The apparatus of claim 1 wherein the power supply applies the electrical pulse across the weakly-ionized plasma to excite atoms in the weakly-ionized plasma and to generate secondary electrons, the secondary electrons ionizing the excited atoms, thereby creating the strongly-ionized plasma.

[c3] The apparatus of claim 1 further comprising a gas exchange means for exchanging the weakly-ionized plasma with a third volume of feed gas while applying the electrical pulse across the third volume of feed gas.

[c4] The apparatus of claim 1 wherein the power supply generates a constant power.

[c5] The apparatus of claim 1 wherein the power supply generates a constant voltage.

[c6] The apparatus of claim 1 wherein the ionization source is chosen from the group comprising an electrode coupled to a DC power supply, an electrode coupled to an AC power supply, a UV source, an X-ray source, an electron beam source, an ion beam source, an inductively coupled plasma source, a capacitively coupled plasma source, and a microwave plasma source.

[c7] The apparatus of claim 1 further comprising a magnet that is positioned to generate a magnetic field proximate to the weakly-ionized plasma, the magnetic field trapping electrons in the weakly-ionized plasma.

[c8] The apparatus of claim 7 wherein the magnet comprises an electro-magnet.

[c9] The apparatus of claim 7 wherein the magnet is movable.

[c10] A method for generating a strongly-ionized plasma, the method comprising:
ionizing a volume of feed gas to form a weakly-ionized plasma;
applying an electrical pulse across the weakly-ionized plasma to generate the strongly-ionized plasma; and
exchanging the strongly-ionized plasma with a second volume of feed gas while applying the electrical pulse across the second volume of feed gas to generate an additional strongly-ionized plasma.

[c11] The method of claim 10 wherein the applying the electrical pulse across the weakly-ionized plasma excites atoms in the weakly-ionized plasma and generates secondary electrons, the secondary electrons ionizing the excited atoms, thereby creating a strongly-ionized plasma.

[c12] The method of claim 10 further comprising exchanging the weakly-ionized plasma with a third volume of feed gas while applying the electrical pulse across the third volume of feed gas.

[c13] The method of claim 10 wherein the applying the electrical pulse comprises applying a quasi-static electric field across the weakly-ionized plasma.

[c14] The method of claim 10 further comprising selecting at least one of a pulse amplitude and a pulse width of the electrical pulse in order to increase an ionization rate of the strongly-ionized plasma.

[c15] The method of claim 10 further comprising selecting at least one of a pulse amplitude and a pulse width of the electrical pulse in order to cause the strongly-ionized plasma to be substantially uniform.

[c16] The method of claim 10 wherein the electrical pulse comprises a rise time that is between about 0.1 microsecond and 10 seconds.

[c17] The method of claim 10 wherein the peak plasma density of the weakly-ionized plasma is less than about 10^{12} cm^{-3}.

[c18] The method of claim 10 wherein the peak plasma density of the strongly-

ionized plasma is greater than about 10^{12} cm^{-3}.

[c19] The method of claim 10 wherein the ionizing the feed gas comprises exposing the feed gas to one of a static electric field, an pulsed electric field, UV radiation, X-ray radiation, electron beam radiation, and an ion beam.

[c20] The method of claim 10 further comprising generating a magnetic field proximate to the weakly-ionized plasma, the magnetic field trapping electrons in the weakly-ionized plasma.

[c21] The method of claim 10 wherein the weakly-ionized plasma reduces the probability of developing an electrical breakdown condition.

[c22] An apparatus for generating a strongly-ionized plasma, the apparatus comprising:
an anode;
a cathode that is positioned adjacent to the anode and forming a gap there between;
an ionization source that generates a weakly-ionized plasma proximate to the cathode; and
a power supply that produces an electric field across the gap, the electric field generating excited atoms in the weakly-ionized plasma and generating secondary electrons from the cathode, the secondary electrons ionizing the excited atoms, thereby creating the strongly-ionized plasma.

[c23] The apparatus of claim 22 wherein the power supply generates a constant power.

[c24] The apparatus of claim 22 wherein the power supply generates a constant voltage.

[c25] The apparatus of claim 22 wherein the electric field comprises a quasi-static electric field.

[c26] The apparatus of claim 22 wherein the electric field comprises a pulsed electric field.

[c27] The apparatus of claim 22 wherein a rise time of the electric field is chosen to increase an ionization rate of the excited atoms in the weakly-ionized plasma.

[c28] The apparatus of claim 22 wherein the weakly-ionized plasma reduces the probability of developing an electrical breakdown condition between the anode and the cathode.

[c29] The apparatus of claim 22 wherein the strongly-ionized plasma is substantially uniform proximate to the cathode.

[c30] The apparatus of claim 22 wherein a dimension of the gap between the anode and the cathode is chosen to increase an ionization rate of the excited atoms in the weakly-ionized plasma.

[c31] The apparatus of claim 22 wherein the ionization source is chosen from the group comprising an electrode coupled to a DC power supply, an electrode coupled to an AC power supply, a UV source, an X-ray source, an electron beam source, an ion beam source, an inductively coupled plasma source, a capacitively coupled plasma source, and a microwave plasma source.

[c32] The apparatus of claim 22 further comprising a magnet that is positioned to generate a magnetic field proximate to the weakly-ionized plasma, the magnetic field trapping electrons in the weakly-ionized plasma proximate to the cathode.

[c33] A method for generating a strongly-ionized plasma, the method comprising:
ionizing a feed gas to generate a weakly-ionized plasma proximate to a cathode; and
applying an electric field across the weakly-ionized plasma in order to excite atoms in the weakly-ionized plasma and to generate secondary electrons from the cathode, the secondary electrons ionizing the excited atoms, thereby creating the strongly-ionized plasma.

[c34] The method of claim 33 wherein the applying the electric field comprises applying a quasi-static electric field.

[c35] The method of claim 33 wherein the applying an electric field comprises

applying the electric field at a constant power.

[c36] The method of claim 33 wherein the applying an electric field comprises applying the electric field at a constant voltage.

[c37] The method of claim 33 wherein the applying the electric field comprises applying an electrical pulse across the weakly-ionized plasma.

[c38] The method of claim 37 further comprising selecting at least one of a pulse amplitude and a pulse width of the electrical pulse in order to increase an ionization rate of the strongly-ionized plasma.

[c39] The method of claim 37 further comprising selecting at least one of a pulse amplitude and a pulse width of the electrical pulse in order to cause the strongly-ionized plasma to be substantially uniform in an area adjacent to a surface of the cathode.

[c40] The method of claim 33 wherein the strongly-ionized plasma is substantially uniform proximate to the cathode.

[c41] The method of claim 33 further comprising generating a magnetic field proximate to the weakly-ionized plasma, the magnetic field trapping electrons in the weakly-ionized plasma.

[c42] The method of claim 33 wherein the weakly-ionized plasma reduces the probability of developing an electrical breakdown condition between the anode and the cathode.

[c43] An apparatus for generating a strongly-ionized plasma, the apparatus comprising:
means for ionizing a volume of feed gas to form a weakly-ionized plasma;
means for applying an electrical pulse across the weakly-ionized plasma to generate the strongly-ionized plasma; and
means for exchanging the strongly-ionized plasma with a second volume of feed gas while applying the electrical pulse across the second volume of feed gas to generate an additional strongly-ionized plasma.

[c44] An apparatus for generating a strongly-ionized plasma, the apparatus comprising:

means for ionizing a feed gas to generate a weakly-ionized plasma proximate to a cathode; and

means for applying an electric field across the weakly-ionized plasma in order to excite atoms in the weakly-ionized plasma and to generate secondary electrons from the cathode, the secondary electrons ionizing the excited atoms, thereby creating the strongly-ionized plasma.